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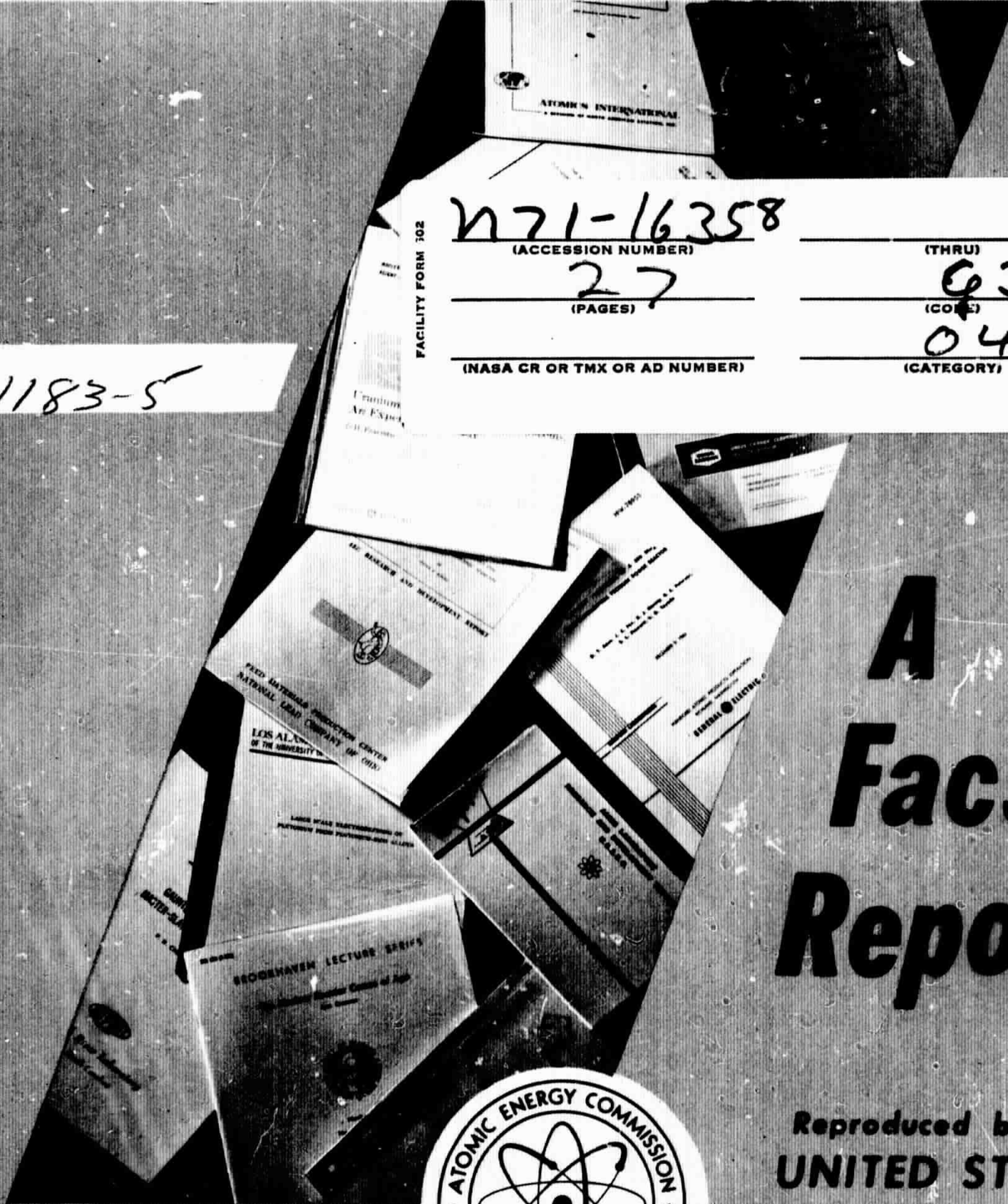

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QUARTERLY RESEARCH REPORT TO THE NASA MANNED SPACECRAFT CENTER

THE MEASUREMENT OF RADIATION EXPOSURE OF ASTRONAUTS BY RADIOCHEMICAL TECHNIQUES

April 6, 1970 Through July 5, 1970

by

R. L. Brodzinski and W. A. Haller

July 15, 1970

Battelle Memorial Institute
Pacific Northwest Laboratories
Richland, Washington 99352

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QUARTERLY RESEARCH REPORT TO THE NASA MANNED SPACECRAFT CENTER

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April 6, 1970 Through July 5, 1970

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ABSTRACT

The urine and feces specimens from the Apollo 13 mission were analyzed for their radionuclide content. Estimates of the cosmic radiation dose received by the astronauts are not accurate due to the low concentrations of the long-lived cosmogenic radionuclides; however, a comparison of the Apollo 13 radionuclide concentrations to those of the Apollo 9 mission yields a dose of < 250 mR for the Apollo 13 mission astronauts. The concentrations of ^{7}Be, ^{22}Na, ^{40}K, ^{59}Fe, ^{60}Co, and ^{137}Cs were determined. The ^{40}K, ^{59}Fe, and ^{137}Cs concentrations in three of the fecal specimens were high compared to previously observed levels, while all other radionuclide concentrations in both feces and urine remained comparable. No ^{147}Pm was observed in any of the samples. It is recommended that in the future at least half of the 24-hour urine collections be used for radionuclide analyses. The concentrations of the radioisotopes observed in the feces from the Apollo 7 through 11 missions and the urine from the Apollo 11 and 12 missions were normalized to the weight of the respective inert element in the specimen. These newly normalized concentrations confirmed all prior conclusions regarding assignment and identification of samples, anomalously high and low concentrations of radionuclides, times of injections of radionuclides, increases and decreases of excretion rates as a function of time, and cosmic radiation doses.

The concentrations of Na, Rb, Cs, Co, Zn, Br, and Se in the urine specimens from the Apollo 12 mission are reported. The daily excretion rates of calcium, potassium, and iron for astronauts from the Apollo 7 through 11 missions are found to be higher than the intake rates by factors of 2.24, 1.54, and 2.2 respectively. The imbalance determined for these three elements strongly dictates the necessity of determining the concentrations of the microconstituents in the foodstuffs. An immediate analysis of the foodstuffs by neutron activation analysis is recommended. Whole blood samples should be collected from each astronaut before, during (if possible), and after each mission for activation analysis of major, minor, and trace elements in order to compare concentrations in the body serum with excretion rates.

The fecal samples from the Apollo 13 mission were analyzed for their glass fiber content. The observed concentrations and total weights of glass fall within the range of results reported for previous missions with but one anomalous sample which had large quantities of extremely long fibers in it.

A piece of the outer thermal coating of the Apollo 7 spacecraft was analyzed for cosmic-ray-induced radioactivity 77 days after splashdown; no radionuclides were observed.

TASK - DETERMINATION OF THE RADIONUCLIDE CONTENT OF FECES AND URINE FROM ASTRONAUTS ENGAGED IN SPACE FLIGHT

Astronauts engaged in space flight are subjected to cosmic radiation which induces radioactive isotopes in their bodies. The radiation dose received from cosmic particles can be determined from the quantities of these induced radionuclides.[1] The concentrations of the induced radioactivities can be determined by direct whole body counting of the astronaut or by indirect measurement, such as counting that fraction of the radionuclides excreted in the feces and urine. This latter approach was used for evaluation of radiation activation during the course of the Apollo 13 mission. In addition, some fallout and naturally occurring radioisotopes have been measured, and variations in their concentrations may serve as tracers of changes in the biological life processes occasioned by the space environment.

The concentrations of the radioisotopes listed in Tables I-VII have been normalized by dividing the decay corrected disintegration rate by the weight of the respective inert element in the sample determined by a technique of instrumental neutron activation analysis.[2-4] The results for urine specimens should be identical to the radionuclide concentration present in the astronaut's body at the time of sampling since all elements excreted in the urine must have been previously metabolized. The data for feces is not quite so clear cut, however, since the quantities of inert elements excreted can be perturbed by unmetabolized elements passing through the gastrointestinal tract or by external addition, as is the case with the sodium salt bactericide. This more precise method of normalizing the data does not change any of the original conclusions [1, 3, 4] regarding assignment and identification of samples, anomalously high and low concentrations of radionuclides, times of injections of radionuclides, increases and decreases of excretion rates as a function of time, and cosmic radiation dose.

The concentrations of the radionuclides in the fecal samples from the Apollo 13 mission are presented in Table VIII normalized to a unit mass of material and decay corrected to the day of splashdown, April 17, 1970. The ^{40}K, ^{59}Fe, and ^{137}Cs activities reported for samples 1, 2, and 4 are high compared to previously observed levels. One possible explanation for this would be a low concentration of water in those fecal samples; however, a check on wet to dry weight ratios showed no deviation from normalcy. The similarity of these three samples with respect to the high radionuclide concentrations may well fingerprint them as being from the same astronaut. The ^{22}Na and ^{60}Co concentrations in all samples appear to be quite routine, and the upper limits reported for the presence of ^{147}Pm again indicate that no significant quantity of ^{147}Pm was ingested by any of the participating astronauts. Dose estimates based on the three reported concentrations of cosmogenic ^{7}Be are difficult for reasons discussed elsewhere.(4) The concentrations of this radionuclide closely resemble those in the Apollo 9 mission fecal samples and thus, by comparison to the dose calculated for that mission, yield a value of < 250 mR for the dose received by Apollo 13 mission astronauts.

The concentrations of the radionuclides in the urine from Apollo 13 astronauts reported in Table IX are all normal when compared to previous missions. The low volume of the samples analyzed reduced the sensitivity of the procedure. It is recommended that in the future at least half of the 24-hour collections obtained both prior and subsequent to flight from each astronaut be analyzed. Any volume less than half of a 24-hour collection has extremely limited usefulness for accurate and sensitive determination of radionuclide content; however, small volumes can be successfully employed in other phases of research, such as neutron activation analysis.

TASK - NEUTRON ACTIVATION ANALYSIS OF FECES AND URINE FROM ASTRONAUTS ENGAGED IN SPACE FLIGHT

This program has been instituted in an attempt to foresee any possible metabolic changes in astronauts caused by prolonged periods of weightlessness or physical inactivity which are manifested by an uptake or loss of an element or elements by their bodies. Of primary concern is the terrestrially observed phenomenon of osteoporosis (loss of skeletal calcium), although changes in the uptake and excretion rates of other essential microconstituents of the body, such as cobalt, iron, selenium, and the alkali metals, are also important.

In previous reports, the measured concentrations of excreted elements have had to be compared to "normal" dietary intakes, and the gains or losses of elements were mostly "best guesstimates." Recently, data has been released by the National Aeronautics and Space Administration(5) regarding the quantities of a few elements ingested by the astronauts of the Apollo 7 through 11 missions. Though this list is by no means complete, it provides a better basis for the uptake or loss of four of the elements — Ca, Na, K, and Fe — which have been measured in the excreta by an instrumental neutron activation analysis technique.(2-4) As will be demonstrated, the need for a complete elemental analysis of the food intake of the astronauts now becomes more important than ever, since conjecture regarding the gain or loss of some body elements by astronauts during space flight is now removed.

Under the assumption that the daily astronaut nutrient intake(5) contains no unreported supplements, the averages for the Apollo 7, 8, 9, 10, and 11 missions were 836, 427.2, 575.3, 832.9, and 1000.3 mg calcium per day respectively. The previously reported (2, 4) corresponding values for fecal excretion are 1140, 1150, 1520, 730, and 1090 mg calcium per day. Making this same comparison for each individual astronaut from the Apollo 9 mission, intake values were 836.4, 854.0, and 808.2 mg calcium for the commander, the lunar module pilot, and the command module pilot respectively, while the corresponding fecal excretion rates were 1190, 1100, and 2260 mg calcium. Since the percentage of total calcium in the feces varies from 69.4% to 91.6%[6, 7] of the total excreted calcium, the excretion rates become even larger in comparison to the intakes. Taking an average fecal excretion percentage of 80%, the total calcium excretion rates become 1430, 1440, 1900, 910, and 1360 mg calcium per day for the Apollo 7 through 11 missions. These values are an average of 2.24 times as high as the intake values and range up to a high of 3.69 times the intake value for the Apollo 9 mission. Even in the best possible case of 91.6% fecal excretion, the total amount of calcium excreted is still an average of 1.96 times as much as the intake, and, in the extreme case of 69.4% fecal excretion, the elimination exceeds the intake by a factor of 2.59. Clearly, if there is no unreported dietary supplement, calcium loss from the astronauts during space flight is occurring.

The rate of calcium loss determined in this work is 896 mg per day based on an 80% fecal excretion percentage. This is equivalent to 0.0853% of the total body calcium per day for a 70 kg standard man,[8] or a loss of 1% of the body calcium over the course of a twelve-day mission. There is a marked difference between this value and the percentage losses determined for some Gemini mission astronauts [9] by roentgenographic techniques on the os calcis. The roentgenograms show a minimum of 2.46% loss for a fourteen-day mission and up to 10.23% for an eight-day mission. Losses for a four-day mission were reported as 6.82% and 9.25%. Clearly, these values do not correspond to the percentage whole body calcium losses observed for the Apollo missions by

the mass balance technique. Possible explanations are that changes were made in the flight program which reduced the calcium loss, or that the calcium concentration in the os calcis is not representative of the whole body calcium inventory.

The determination of sodium in the feces is always a questionable task due to the frequent addition of sodium orthophenylphenol, a bactericide, to the specimens. The determination of potassium may also be questionable since the concentration of potassium in the bactericide has not yet been determined. If the potassium concentrations in the feces have not been significantly perturbed by the extraneous addition of potassium, then the fecal excretion rates are 311 and 350 mg/day for the Apollo 9 and 11 missions respectively and 499 mg/day for the commander of the Apollo 8 mission.[2-4] Since only 16.5% of the total potassium eliminated is found in the feces,[6] the total excretion rates for these three cases are 1880, 2120, and 3020 mg/day which can be compared with the respective potassium intakes of 1590, 1229, and 1751 mg/day.[5] These excretion rates are an average of 1.54 times as high as the intake values, and although this loss of potassium is not quite as high as the loss of calcium, the importance of potassium in maintaining the electrolytic balance of the body also renders this mass imbalance significant if, again, the astronauts are not taking an unreported potassium supplement and are not losing body potassium due to large weight losses.

Almost all iron eliminated from the body is found in the feces,[6] and excretion rates of 16, 13.3, 14, and 16.4 mg/day have been reported [2-4] for the Apollo 7, 8, 9, and 11 missions respectively. The corresponding daily intakes of iron were 8.1, 5.0, 6.5, and 8.0 mg.[5] Thus, the astronauts are also losing iron from their bodies during the course of a mission as the excretion rates are an average of 2.2 times the intake rates. The intake values reported are not sufficient to meet the 10 to 12 mg daily requirement.[10]

Summarizing the above observations, the daily excretion rates of calcium, potassium, and iron are found to be higher than the intake rates for astronauts engaged in space flight. The sodium content of the foodstuffs has also been measured, but comparison to excretion is impossible due to contamination of the fecal samples with a sodium salt bactericide. It is doubtful that weight loss during a mission can account for the calcium, potassium, and iron losses, but this possibility will be thoroughly examined. The imbalance determined for these three elements also strongly dictates the necessity of determining the concentrations of the microconstituents in the foodstuffs for comparison with the already determined excretion rates of these elements. An analysis of the foodstuffs should be accomplished as soon as possible. In addition, since the concentrations of elements excreted in the urine and feces do not necessarily accurately reflect the concentrations in the body serum, whole blood samples collected from the astronauts both prior to and immediately following a mission (preferably during if possible) should be analyzed for changes in elemental concentrations.

APOLLO 12

A previously described technique of instrumental neutron activation analysis[1, 2] was used to determine the concentrations of Na, Rb, Cs, Co, Zn, Br, and Se in the urine specimens collected before and after the Apollo 12 mission. The results are presented in Tables X through XII. A critique of the uncertainties associated with the procedure appears elsewhere.[4] No systematic deviations between the preflight and postflight concentrations were observed for any of the elements, but this does not exclude the possibility of gross deviations during flight. The results of the analyses of elemental concentrations in the fecal samples from the Apollo 12 mission

are not yet complete, and a more complete treatise of the urine data will be given when the fecal data is reported.

Average urinary excretion rates of 2.47 g Na/day, 3.5 mg Rb/day, 7.8 μg Cs/day, 2.3 μg Co/day, 710 μg Zn/day, 4.1 mg Br/day, and 63 μg Se/day are calculated for the Apollo 12 mission from the data in Tables X, XI, and XII. The corresponding figures for the Apollo 11 mission are 2.77 g Na/day, 3.6 mg Rb/day, 10.4 μg Cs/day, 3.8 μg Co/day, 707 μg Zn/day, 2.52 mg Br/day, and 45 μg Se/day.[4] These rates are certainly comparable for the two missions, although only one comparison to intake values can be made at this time. These sodium excretion values are similar to the ingestion rate of sodium reported for the Apollo 11 mission,[5] and if the inflight excretion rates were the same as the pre- and postflight rates, the sodium balance would be preserved.

TASK - GLASS FIBERS IN ASTRONAUT FECAL SAMPLES

During the course of each manned Apollo mission, it has been observed by the astronauts that significant amounts of glass fibers were present within the atmosphere of the spacecraft. In order to determine the amount and origin of fibers which were ingested by the astronauts, the inflight fecal samples, which were collected and stored onboard the spacecraft, were analyzed for their glass fiber content.

The results of the analysis of the six returned fecal samples from the Apollo 13 mission, which were analyzed for glass fiber content according to a procedure described in an earlier report,[1] are presented in Table XIII. The sample numbers are completely arbitrary and have been assigned for identification purposes only. Alpha and beta fiber types have been grouped together due to the similarities of the fibers; types DE and G have also been grouped together for the same reason. The observed concentrations and total weights of glass fall within the range of results reported for previous missions. The total weight of glass in all samples divided by the total elapsed time of the mission and by the number of astronauts yields an average elimination rate of 68.86 μg/man day, which is again within the range of that observed for other missions.[1, 3, 4] Sample #5 contained significantly more fiber glass than any other sample and had one cluster of beta fibers still held together with the bonding agent. In addition, the glass fibers observed in this sample were unusually long (as much as 5 mm) compared to the average fiber length of all other missions (0.4 mm).

TASK - INDUCED RADIONUCLIDES IN SPACECRAFT

A 0.1197 g piece of the outer skin from the Apollo 7 spacecraft was counted in these laboratories 77 days after splashdown of that mission. No radionuclides were observed to be present in the foil. The upper limit for the ^{22}Na concentration was 0.47 dis/min/g skin. Comparing this value to that observed for the ^{22}Na activity observed in the Apollo 8 mission skin,[1] an upper limit of 360 protons $cm^{-2}sec^{-1}$ above 30 MeV is calculated to have been incident on the Apollo 7 spacecraft.

EXPENDITURES

The following table documents the expenditures according to task and total cost incurred from April 6, 1970, through July 5, 1970, for the work reported herein.

TASK	EXPENDITURES
Determination of the Radionuclide Content of Feces and Urine From Astronauts Engaged in Space Flight	$ 1,704
Neutron Activation Analysis of Feces and Urine From Astronauts Engaged in Space Flight	$ 3,939
Glass Fibers in Astronaut Fecal Samples	$ 691
Induced Radionuclides in Spacecraft	$ 190
Promethium-147 in Space Capsule Environment	$ 221
TOTAL COSTS	$ 6,745

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TABLE I

RADIOACTIVITY IN FECES FROM APOLLO 7 ASTRONAUTS*

Sample # or Astronaut	Flight Period	dis/min ^{22}Na per g Na	dis/min ^{51}Cr per g Cr	dis/min ^{59}Fe per g Fe	dis/min ^{60}Co per g Co	dis/min ^{137}Cs per g Cs
B	Pre		$(4.248 \pm 0.055)\cdot 10^7$	630 ± 150		$(8.3 \pm 1.4)\cdot 10^6$
C	Pre		$(4.32 \pm 0.10)\cdot 10^7$			
S/N 2276	In		$(3.137 \pm 0.094)\cdot 10^7$	1410 ± 220		$(7.8 \pm 1.3)\cdot 10^6$
S/N 2277	In		$(1.678 \pm 0.042)\cdot 10^7$			$(6.4 \pm 1.0)\cdot 10^6$
S/N 2278	In	0.64 ± 0.47	$(2.137 \pm 0.021)\cdot 10^7$	410 ± 120		$(5.2 \pm 1.2)\cdot 10^6$
S/N 2280	In	1.2 ± 0.7	$(2.917 \pm 0.026)\cdot 10^7$	810 ± 370		$(5.6 \pm 2.0)\cdot 10^6$
S/N 2282	In		$(1.511 \pm 0.041)\cdot 10^7$			$(5.59 \pm 0.90)\cdot 10^6$
S/N 2292	In		$(2.793 \pm 0.034)\cdot 10^7$			$(1.6 \pm 1.1)\cdot 10^6$
S/N 2299	In		$(2.498 \pm 0.032)\cdot 10^7$	3470 ± 280		$(2.42 \pm 0.20)\cdot 10^7$
S/N 2300	In	0.50 ± 0.26	$(1.959 \pm 0.071)\cdot 10^7$	930 ± 200		$(1.40 \pm 0.14)\cdot 10^7$
S/N 2312	In		$(4.771 \pm 0.057)\cdot 10^7$	730 ± 180		$(6.6 \pm 1.2)\cdot 10^6$
A	Post	5.6 ± 3.0	$(3.105 \pm 0.050)\cdot 10^7$	3450 ± 290		
C	Post		$(4.159 \pm 0.037)\cdot 10^7$	$(3.609 \pm 0.032)\cdot 10^4$	$(1.956 \pm 0.068)\cdot 10^6$	$(1.461 \pm 0.096)\cdot 10^7$

* The radioactivities have been normalized by dividing the disintegration rate by the weight of the inert element and decay correcting to the splashdown date, 10/22/68.

TABLE II

RADIOACTIVITY IN FECES FROM APOLLO 8 ASTRONAUTS*

Sample #	dis/min ^{22}Na per g Na	dis/min ^{51}Cr per g Cr	dis/min ^{59}Fe per g Fe	dis/min ^{137}Cs per g Cs
1		$(1.943 \pm 0.031)\cdot 10^7$	880 ± 220	$(4.58 \pm 0.48)\cdot 10^6$
2		(6.78[illegible] $\pm$ 0.088)$\cdot 10^7$	1380 ± 260	$(9.42 \pm 0.78)\cdot 10^6$
3	0.77 ± 0.61	$(1.291 \pm 0.028)\cdot 10^7$	2230 ± 410	$(5.39 \pm 0.74)\cdot 10^6$

* The radioactivities have been normalized by dividing the disintegration rate by the weight of the inert element and decay correcting to the splashdown date, 12/27/68.

TABLE III

RADIOACTIVITY IN FECES FROM APOLLO 9 ASTRONAUTS*

Sample # or Astronaut	Flight Period	dis/min ^{51}Cr per g Cr	dis/min ^{59}Fe per g Fe	dis/min ^{60}Co per g Co	dis/min ^{137}Cs per g Cs
1	In	$(4.9 \pm 1.1)\cdot 10^{6}$	3030 ± 710	$(4.8 \pm 1.0)\cdot 10^{5}$	
3	In	$(1.241 \pm 0.024)\cdot 10^{7}$	1690 ± 240	$(3.2 \pm 1.7)\cdot 10^{4}$	$(9.51 \pm 0.88)\cdot 10^{6}$
4	In	$(4.228 \pm 0.076)\cdot 10^{7}$	1870 ± 220		$(1.95 \pm 0.13)\cdot 10^{7}$
6	In	$(1.354 \pm 0.085)\cdot 10^{7}$	3450 ± 480		$(2.13 \pm 0.27)\cdot 10^{7}$
8	In		9400 ± 2300	$(3.5 \pm 2.2)\cdot 10^{5}$	
Schweickart	168:00	$(2.325 \pm 0.035)\cdot 10^{7}$	740 ± 110	$(4.2 \pm 2.0)\cdot 10^{4}$	$(5.20 \pm 0.61)\cdot 10^{6}$
D.R.S.	113:00	$(6.98 \pm 0.33)\cdot 10^{6}$	269 ± 88	$(4.1 \pm 2.3)\cdot 10^{4}$	$(4.93 \pm 0.77)\cdot 10^{6}$
D.R.S.	190:25	$(7.26 \pm 0.29)\cdot 10^{6}$	1170 ± 160	$(2.7 \pm 1.4)\cdot 10^{4}$	$(5.31 \pm 0.78)\cdot 10^{6}$
D.R.S.	235:00	$(7.28 \pm 0.31)\cdot 10^{6}$	1750 ± 170	$(4.1 \pm 1.4)\cdot 10^{4}$	$(7.47 \pm 0.61)\cdot 10^{6}$

* The radioactivities have been normalized by dividing the disintegration rate by the weight of the inert element and decay correcting to the splashdown date, 3/13/69.

TABLE IV

RADIOACTIVITY IN FECES FROM APOLLO 10 ASTRONAUTS*

Sample #	dis/min ^{22}Na per g Na	dis/min ^{59}Fe per g Fe	dis/min ^{60}Co per g Co	dis/min ^{137}Cs per g Cs
S/N 3512	0.57 ± 0.49	730 ± 190	$(6 \pm 4)\cdot 10^{4}$	$(3.41 \pm 0.42)\cdot 10^{6}$
S/N 3527	15 ± 10	620 ± 200		$(4.65 \pm 0.85)\cdot 10^{6}$

* The radioactivities have been normalized by dividing the disintegration rate by the weight of the inert element and decay correcting to the splashdown date, 5/26/69.

TABLE V

RADIOACTIVITY IN FECES FROM APOLLO 11 ASTRONAUTS*

Sample #	dis/min ^{59}Fe per g Fe	dis/min ^{60}Co per g Co	dis/min ^{137}Cs per g Cs
1	9500 ± 1700	$(4.8 \pm 2.5)\cdot10^4$	$(1.24 \pm 0.12)\cdot10^7$
2		$(3.4 \pm 1.8)\cdot10^4$	$(6.29 \pm 0.95)\cdot10^6$

* The radioactivities have been normalized by dividing the disintegration rate by the weight of the inert element and decay correcting to the splashdown date, 7/24/69.

TABLE VI

RADIOACTIVITY IN URINE FROM APOLLO 11 ASTRONAUTS*

Astronaut	Flight Period	dis/min ^{22}Na per g Na	dis/min ^{60}Co per g Co	dis/min ^{137}Cs per g Cs
Aldrin	Pre			$(2.2 \pm 1.4)\cdot10^6$
Armstrong	Pre			$(5.17 \pm 0.82)\cdot10^6$
Collins	Pre	0.51 ± 0.40		$(1.07 \pm 0.12)\cdot10^7$
Aldrin	Post	0.48 ± 0.30	$(1.3 \pm 1.1)\cdot10^6$	$(7.2 \pm 6.8)\cdot10^5$
Armstrong	Post	0.43 ± 0.23		$(2.04 \pm 0.80)\cdot10^6$
Collins	Post			$(2.4 \pm 1.4)\cdot10^6$

* The radioactivities have been normalized by dividing the disintegration rate by the weight of the inert element and decay correcting to the splashdown date, 7/24/69.

TABLE VII

RADIOACTIVITY IN URINE FROM APOLLO 12 ASTRONAUTS*

Astronaut	Flight Period	dis/min ^{22}Na per g Na	dis/min ^{60}Co per g Co	dis/min ^{137}Cs per g Cs
Bean	F-30			$(1.80 \pm 0.17)\cdot 10^7$
Conrad	F-30	0.49 ± 0.19		$(5.78 \pm 0.93)\cdot 10^6$
Gordon	F-30			$(2.36 \pm 0.27)\cdot 10^7$
Bean	F-15			$(1.77 \pm 0.16)\cdot 10^7$
Conrad	F-15			$(1.15 \pm 0.17)\cdot 10^7$
Gordon	F-15			$(5.22 \pm 0.31)\cdot 10^7$
Bean	ASAP Post			$(1.98 \pm 0.12)\cdot 10^8$
Conrad	ASAP Post			$(4.51 \pm 0.41)\cdot 10^7$
Gordon	ASAP Post			$(1.45 \pm 0.43)\cdot 10^7$
Bean	Day 2 Post		$(5.7 \pm 3.0)\cdot 10^6$	$(1.97 \pm 0.35)\cdot 10^7$
Conrad	Day 2 Post	2.2 ± 1.1		
Gordon	Day 2 Post	4.4 ± 3.6		

* The radioactivities have been normalized by dividing the disintegration rate by the weight of the inert element and decay correcting to the splashdown date, 11/24/69.

TABLE VIII

RADIOACTIVITY IN FECES FROM APOLLO 13 ASTRONAUTS

dis/min/g Feces on 4/17/70

Sample	^{7}Be	^{22}Na	^{40}K	^{59}Fe	^{60}Co	^{137}Cs	^{147}Pm
#1		0.0035 ± 0.0027	18.16 ± 0.25	4.79 ± 0.10	0.0091 ± 0.0037	2.759 ± 0.034	≤ 0.3
#2		0.0062 ± 0.0027	13.12 ± 0.23	4.135 ± 0.094	0.0095 ± 0.0035	3.580 ± 0.034	≤ 0.19
#3	4.07 ± 0.53		7.02 ± 0.51		0.021 ± 0.009		≤ 0.78
#4	0.503 ± 0.059	0.0099 ± 0.0031	19.77 ± 0.25	4.998 ± 0.097	0.013 ± 0.004	1.663 ± 0.033	≤ 0.078
#5	1.33 ± 0.14		11.12 ± 0.22	0.546 ± 0.083	0.004 ± 0.003	0.138 ± 0.028	≤ 0.17
#6		0.0037 ± 0.0027	10.07 ± 0.23		0.004 ± 0.003		≤ 0.096

TABLE IX

RADIOACTIVITY IN URINE FROM APOLLO 13 ASTRONAUTS

Astronaut	Flight Period	^7Be	^{22}Na	^{40}K	^{59}Fe	^{60}Co	^{137}Cs
		dis/min/ml on 4/17/70					
Haise	F-5	0.182 ± 0.076	0.0014 ± 0.0009	1.809 ± 0.072	0.095 ± 0.028		0.0612 ± 0.0097
Lovell	F-5	0.283 ± 0.074	0.0012 ± 0.0008	2.210 ± 0.070	0.063 ± 0.027	0.0047 ± 0.0013	0.0314 ± 0.0092
Haise	ASAP Post	0.68 ± 0.14		2.97 ± 0.13			0.078 ± 0.017

TABLE X

Ca, Na, Rb, AND Cs CONCENTRATIONS IN APOLLO 12 ASTRONAUT URINE SAMPLES

Astronaut	Flight Period	Ca ppm	Ca mg/day	Na ppm	Na g/day	Rb ppm	Rb mg/day	Cs ppm	Cs μg/day
Bean	F-30	<400	<256	4200	2.69	2.4	1.5	0.0058	3.7
Conrad	F-30	<400	<456	3300	3.76	2.2	2.5	0.0071	8.1
Gordon	F-30	<400	<612	350	0.54	2.0	3.1	0.0030	4.6
Bean	F-15	<400	<560*	2900	4.06*	2.1	2.9*	0.0049	6.9*
Conrad	F-15	<400	<560*	1960	2.74*	1.9	2.7*	0.0041	5.7*
Gordon	F-15	<400	<560*	1800	2.52*	1.4	2.0*	0.0025	3.5*
Bean	ASAP Post	<400	<560*	1600	2.24*	4.3	6.0*	0.0033	4.6*
Conrad	ASAP Post	<400	<560*	1770	2.48*	3.4	4.8*	0.0089	12.5*
Gordon	ASAP Post	<400	<560*	890	1.25*	1.9	2.7*	0.0073	10.2*
Bean	Day 2 Post	<400	<560*	1900	2.66*	2.1	2.9*	0.0103	14.4*
Conrad	Day 2 Post	<400	<560*	2300	3.22*	6.3	8.8*	0.0087	12.2*
Gordon	Day 2 Post	<400	<560*	1060	1.48*	1.6	2.2*	0.0055	7.7*

* Assuming an average 1400 g/day excretion of urine [6]

TABLE XI

Co AND Zn CONCENTRATIONS IN APOLLO 12 ASTRONAUT URINE SAMPLES

Astronaut	Flight Period	Co ppm	Co µg/day	Zn ppm	Zn µg/day
Bean	F-30	0.0016	1.0	0.93	600
Conrad	F-30	0.0020	2.3	0.24	270
Gordon	F-30	0.0008	1.2	0.40	610
Bean	F-15	0.0013	1.8*	0.4	560*
Conrad	F-15	0.0014	2.0*	0.28	390*
Gordon	F-15	0.0009	1.3*	0.29	410*
Bean	ASAP Post	0.0012	1.7*	0.2	280*
Conrad	ASAP Post	0.0039	5.5*	0.61	850*
Gordon	ASAP Post	0.0024	3.4*	0.7	980*
Bean	Day 2 Post	0.0017	2.4*	1.4	1960*
Conrad	Day 2 Post	0.0010	1.4*	0.51	710*
Gordon	Day 2 Post	0.0028	3.9*	0.64	900*

*Assuming an average 1400 g/day excretion of urine(6)

TABLE XII

Be, Se, AND Hg CONCENTRATIONS IN APOLLO 12 ASTRONAUT URINE SAMPLES

Astronaut	Flight Period	Br ppm	Br mg/day	Se ppm	Se µg/day	Hg ppm	Hg µg/day
Bean	F-30	7.4	4.7	0.039	25	<0.01	<6.4
Conrad	F-30	5.4	6.2	0.044	50	<0.01	<11
Gordon	F-30	0.79	1.2	0.032	49	<0.01	<15
Bean	F-15	7.8	10.9*	0.034	48*	<0.01	<14*
Conrad	F-15	2.9	4.1*	0.044	62*	<0.01	<14*
Gordon	F-15	1.6	2.2*	0.021	29*	<0.01	<14*
Bean	ASAP Post	4.0	5.6*	0.051	71*	<0.01	<14*
Conrad	ASAP Post	1.8	2.5*	0.058	81*	<0.01	<14*
Gordon	ASAP Post	1.7	2.4*	0.024	34*	<0.01	<14*
Bean	Day 2 Post	2.8	3.9*	0.076	106*	<0.01	<14*
Conrad	Day 2 Post	2.6	3.6*	0.073	102*	<0.01	<14*
Gordon	Day 2 Post	1.02	1.4*	0.068	95*	<0.01	<14*

* Assuming an average 1400 g/day excretion of urine(6)

TABLE XIII

GLASS FIBER CONCENTRATIONS IN APOLLO 13 ASTRONAUT FECAL SAMPLES

Sample	Aliquot (Grams)	Observed Fibers		Defecation Weight (Grams)	Fibers/g Feces		Fibers/Defecation		μg Glass Per g Feces	μg Glass Per Defecation
		α&β	DE&G		α&β	DE&G	α&β	DE&G		
#1	2.8291g	343	12	165.8	121	4.2	20,100	700	1.02	169
#2	2.5293g	592	8	108.3	234	3	25,300	300	1.78	192
#3	3.7607g	127	1	35.0	33.8	0.3	1,180	9	0.249	8.71
#4	3.9176g	96	2	269.4	25	0.5	6,600	100	0.19	52
#5*	3.5263g	2526	9	149.6	716.3	3	107,200	400	5.16	772
#6	3.6491g	100	4	155.1	27.4	1	4,250	200	0.236	36.6

* Does not include a cluster of approximately 50 beta fibers still held together with the bonding agent

END

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